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The long commute: Southern Royal Albatross (*Diomedea epomophora*) foraging trips during incubation

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Abstract

Southern royal albatross from the Campbell Islands employ a 'commute, forage, commute' foraging strategy. During commuting phases birds undertook rapid directional flight with a straight-line distance of 180 to 800 km over 24 hours. In foraging phases their range extensions were less than 180 km per 24 hour interval, and they made frequent tight turns and frequent landings. Speed of travel between successive uplinks was significantly higher during commuting phases (28.6 kph ± 1.9 SE) than foraging phases (15.1 kph ± 1.4 SE). Wind strength and direction influenced the timing of return to the colony. Southern royal albatross covered greater distances at more favourable wind angles relative to flight track (broad reach and close reach) than in head, tail or direct side winds. Birds of low mass (< 9 kg) made fewer landings in winds above 40 kph than in lighter winds whereas heavier birds had a similar level of landing activity across all wind speed bands.

Keywords: Campbell Island - *Diomedea epomophora* - foraging behaviour - satellite-tracking - seabird.

Introduction

Appropriate management of seabirds depends on an adequate understanding of their ecology and behaviour. Individual species' foraging strategies, ecology, areas, activity, energetics and flight characteristics make them vulnerable in different ways to anthropogenic and other disturbances (Lawton *et al* 2008). Several studies have shown that foraging behaviour is often species specific (Phillips *et al* 2007, Pinaud & Weimerskirch 2007, Lawton *et al* 2008). Weimerskirch (1997) identified patterns of foraging trips made by breeding albatross of different species and at different stages of the breeding cycle. Three southern royal albatross (*Diomedea epomophora*) studied in 1997 had foraging flights during incubation that seemed to differ from those of the closely related wandering albatross (*Diomedea exulans*). They undertook relatively short, rapid commuting flights to a confined zone where they foraged for several days before returning rapidly and relatively directly to the colony (Waugh *et al*. 2002).

Low wind speed has been found to influence flight performance by reducing "ground speed" in several albatross species (Alerstam *et al.* 1993). Wandering albatross mean flight speeds between satellite fixes varied little with wind speeds above 15 knots but were lower at 0 – 5 knots and mean flight speeds were lower in males than females at most wind speeds (Salamolard & Weimerskirch 1993). A bird flying slowly covers less water and, when prey is sparsely or randomly distributed, is likely to encounter fewer prey items than if flying at higher speeds. Lack of wind has been suggested to increase the energy expenditure of petrels and albatross (Furness & Bryant 1996).

Weimerskirch *et al.* (2000) found that the energetic cost of flying in favourable wind directions was low, in some cases close to basal metabolic rate for wandering albatross. The most favourable winds were found to be in the stern quarter (between tail and side winds). The birds used strategies that increased the likelihood of encountering favourable wind directions to the extent that unfavourable head winds were encountered on less than 4% of the tracks between fixes. The birds could achieve this, despite being constrained to returning to their starting point at the colony, by predicting prevailing wind directions in different zones of the southern Indian Ocean (Weimerskirch *et al.* 2000).

In this study we look for evidence of strategies that may minimise foraging costs in southern royal albatross. We observe the impact that wind direction and strength have on the pattern of southern royal albatross foraging flights. We examine whether southern royal albatross employ a 'commute, forage, commute' pattern during incubation, as suggested by Waugh *et al.* (2002). We also examine the influence of wind speed on the timing of identifiable phases of the foraging trip and on landing activity. We investigate the relationship between wind speed and take-off and landing activity in southern royal albatross of different weight categories.

Methods

Ten southern royal albatross at Campbell Island (52°33'S, 169°09'E) were satellite-tracked during incubation between 10 January and 7 February 1999. The transmitters were resin coated Telonics and Microwave Platform Terminal Transmitters (PTTs) with short whip aerials and weighed 20 g. Transmitters were set to transmit every 90 seconds. Locations were received through the ARGOS system (Argos, CSL, Toulouse, France). The units were attached to dorsal feathers using Tesa surgical-grade tape, and removed after one foraging trip.

Landing activity and time spent on the water was recorded by a miniature wet-dry data logger attached to each of the 10 southern royal albatross. The data logger was cylindrical in shape and attached to a Davik band on the tarsus using Tesa fabric adhesive tape. A wet or dry reading was logged every 15 seconds throughout each bird's foraging trip.

The threshold for rejection of low-quality satellite locations was a flight speed in excess of 90 km per hour between successive uplinks after subtracting the time the bird had spent on the water during that time interval.

Data processing:

The purpose-built software package "Diomedea" was used to integrate the satellite locations and activity data. Distances and speeds travelled between locations were calculated and intermediate positions interpolated for every minute after matching with the wet-dry recorder data to subtract time spent on the water. Birds' satellite fixes and interpolated intermediate positions throughout their foraging trip were plotted. Time spent in the air and time spent on the water were plotted separately to enable us to identify foraging areas.

To further examine the foraging strategies by integrating the birds' temporal and spatial movements, calculation was made of range extension (change in distance from island) per 24 hour period as a running minute-by minute calculation. Range extensions were then plotted against time, making it possible to differentiate periods of directional travel ('commuting') from periods of localised searching ('foraging') and to see the overall pattern of the bird's movement through time.

To examine the relationships between bird location and activity and wind strength and direction, the satellite tracking and activity data were integrated with meteorological records supplied by Metéo-France. These records were interpolated from multiple data collection methods and had a spatial resolution of 1.5º latitude by 1.5º longitude, and a temporal resolution of 12 hours.

To investigate the influence of wind speed on the timing of commuting within the overall trip, wind speed during 'commute' and 'forage' phases were compared. Wind direction was compared with the birds' flight course during commuting.

The birds' angle of flight relative to local wind direction was calculated at one-minute intervals during each bird's trip. The angle of flight was taken to be the angle between two successive satellite points and the wind data was taken at the bird's estimated position. The convention relating to vessels was used; i.e. the bird's direction is given as the bearing to which the bird is flying; whereas the wind direction is the bearing from where the wind originated. Hence a relative wind direction of 180° was a tail wind, and 0° degrees a head wind. Left-right symmetry was assumed, so values from 180° to 360° were combined with the corresponding sector between 0° and 180°.

Analysis of the birds' use of different angles of flight relative to wind direction was done by dividing each bird's trip record: a) into commuting and foraging phases by the method described above; and b) within those categories, creating 9 bands of 20 degrees each between 0° and 180°. Mean distance flown, flight speed and wind speed were calculated within each 20° band.

Landing activity at different wind strengths was analysed, with the number of landings and take-offs by light birds (6 females < 9kg) compared with those of heavy birds (three males and one female > 9 kg) across a range of wind speeds.

Results

Foraging strategies

Eight of the ten southern royal albatrosses foraging trips showed a pattern of the type 'commute, forage, commute' with one or two principal foraging destinations each, within or close to the Campbell Plateau or Chatham Rise. Two of the three males exhibited more of a hybrid foraging strategy, staying over the Campbell Plateau but moving as if searching and foraging at many sites while on the move.

There was a clear bimodal distribution of range extensions, with the upper limit for shorter distances found to be 180 km between 24-hourly positions (Figure 1). For subsequent analyses of the two phases of trips, the 180 km threshold was used to divide commuting periods (range extension >180 km per 24 hours) from

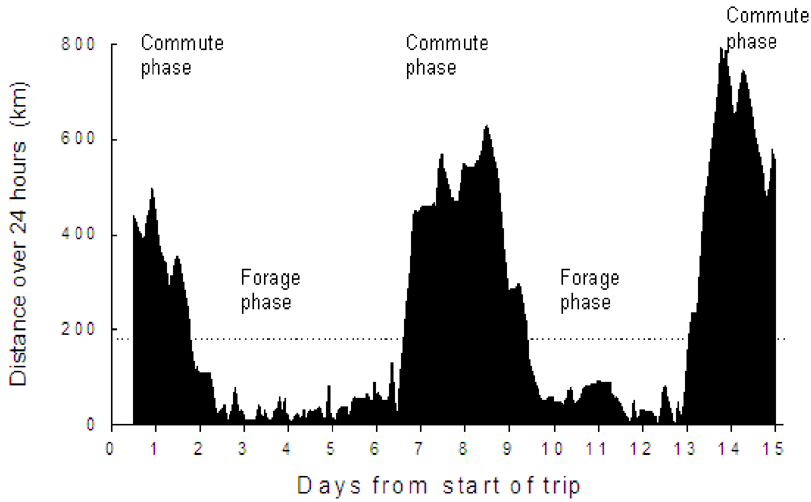
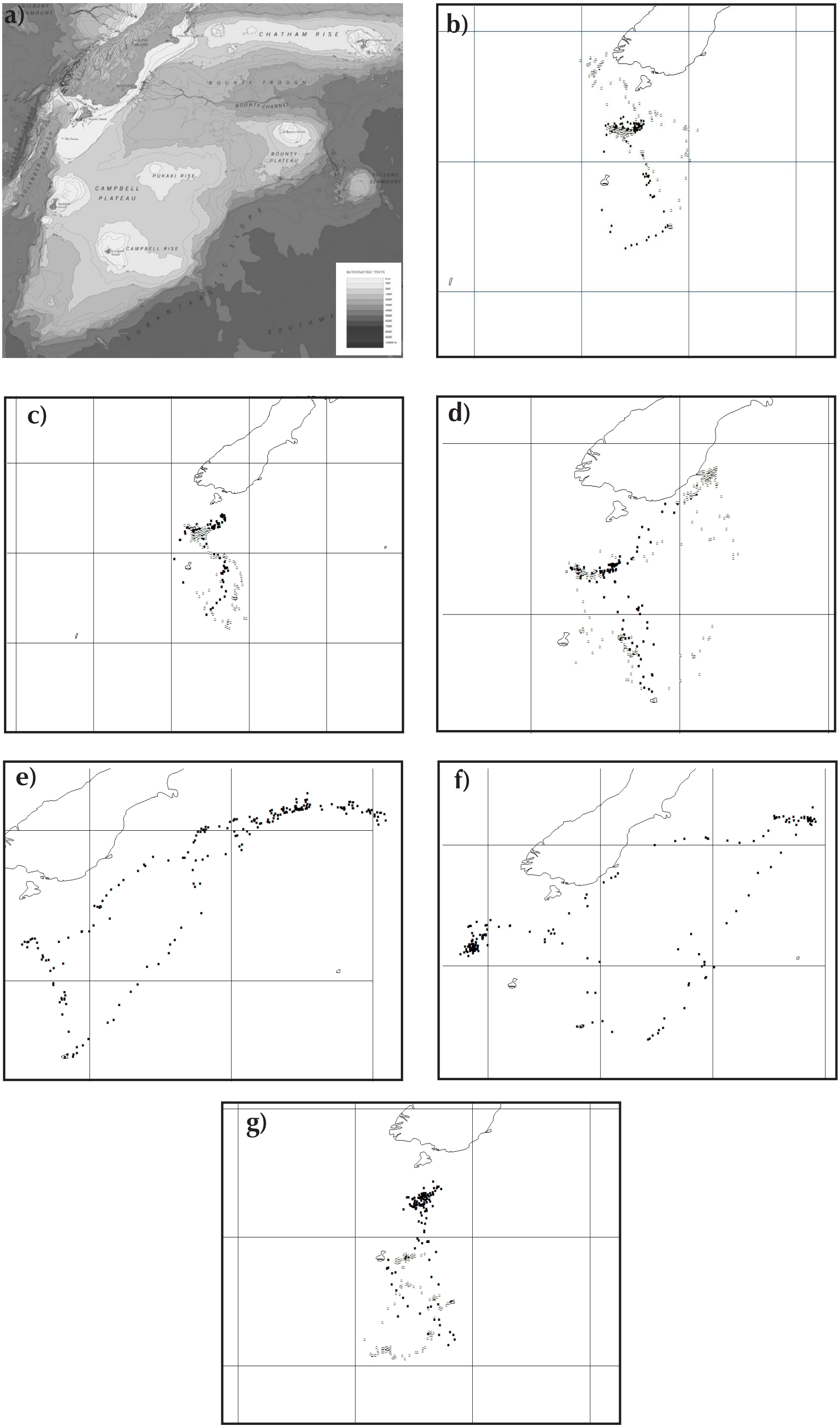


Figure 1. Distance over time: Bird G. Each vertical bar shows the distance between locations 24 hours apart, plotted every 10 minutes. She commuted from Campbell Island to the north Macquarie Ridge (days 1 & 2), foraged there for 4 days then commuted to the Chathams Rise (days 7-9) where she foraged for 3 days before commuting back to Campbell Island (days 13-16).

foraging periods (range extension <180 km per 24 hours). A simple three-phase commute – forage – commute pattern to a single main foraging destination (the Snares Islands hotspot) was most clearly defined in four foraging trips (Birds A, B, C, and D). Bird A carried out the least complicated foraging trip of all the tracked birds, taking just 13 hours to reach the Snares hotspot on a curved course, then foraging within a concentrated area before returning on a direct route to Campbell Island.

Figure 2 shows the flight tracks of all the albatross, with two contrasting flight tracks in each map, apart from Birds F and G which are mapped separately. Bird F undertook a commute phase of more than 24 hours to the Chatham Rise, with a peak 24-hour range extension of 845 km. She also flew greater distances during the foraging phase along the southern edge of the Rise than did most of the other birds during foraging. Her return commute towards Campbell Island was interrupted by short bouts of foraging. Birds E, G, and J also switched from foraging to commuting for a period in the middle of their trip, travelling on to a new foraging site. Bird G had the most extensive range of the ten birds – west to seamounts of the northern Macquarie Ridge then north to the Chatham Rise. Bird E prospected at two sites before flying north to the Otago coast (SE South Island) where she was stranded by several days of light wind.

Figure 2. (overleaf): Named features, and undersea terrain showing plateaus and troughs; along with a summary of the foraging flight track for all 10 birds. Positions shown indicate points at which the birds were on the water based on interpolation from satellite fixes. Two contrasting birds flights are given on each flight display apart from Birds F and G, who flew a considerable distance further north. a) Bathymetry of the New Zealand Subantarctic area identifying areas birds in this study used (figure modified from NIWA); b) Birds A (closed square) & H (open circle); c) Birds B (closed square) & C (open circle); d) Birds D (closed square) & E (open circle); e) Bird F (closed square); f) Bird G (closed square); g) Birds I (closed square) & J (open circle).


a)
CHATHAM RISE
BOUNTY TROUGH
BOUNTY CHANNEL
BOUNTY PLATEAU
PUKAKI RISE
CAMPBELL PLATEAU
CAMPBELL RISE
SUBANTARCTIC SLOPE
BOLLONS SEAMOUNT
BATHYMETRIC TINTS
b)
c)
d)
e)
f)
g)

Two of the three male birds (I and J) foraged to the south of Campbell Island then looped north, while the third (H) flew further west than any of the others except bird G. They exhibited lower peak commuting range extensions than most of the females (barely exceeding 400 km/day), and from their landing patterns, birds H and J foraged at numerous sites along their route rather than at clearly defined destinations. While their flights suggested a hybrid strategy between a clear commute-forage-commute and the continuous searching flight seen in wandering albatrosses (Weimerskirch 1997), the sample is too small to suggest a sex difference in foraging strategy.

Wind speed

Wind speed appeared to play an important role in the timing of the return commute to Campbell Island. All of the birds appeared to start returning to the colony when wind speed increased to relatively high levels.

Wind direction relative to flight track

Commute phases were generally conducted with side or stern quarter winds. There were two cases of birds attempting to commute into head winds: bird E, whose initial commute track was erratic and slow as she attempted to travel upwind in NNW winds; and bird C, who encountered strong SW winds while returning to Campbell Island and altered her course, taking her further from the island. The four birds that flew on a southerly sector course from the island did so in northwest conditions, and changed course towards the north once the wind direction changed.

Analysis of wind speed, wind angle and displacement speed

The mean wind speed for all birds during commuting (23.3 kph ± 1.7 SE) was significantly higher than during foraging (16.6 kph ± 1.9 SE) (2-tailed paired sample test, t = -4.27, df 9; P=0.002). The mean displacement rate between successive uplinks for all birds during commuting (28.6 kph ± 1.93 SE) was significantly higher than during foraging (15.1 kph ± 1.4 SE) (t = -8.17; df 9; P = 0.001). The following results are for commuting and foraging phases combined. Time spent on the water was excluded. Commuting and foraging data are plotted separately in Figures 3 and 4. Winds from less favourable directions relative to the bird's flight track (0° to 40° - upwind or head winds; 80° to 100° - wind abeam or direct side wind

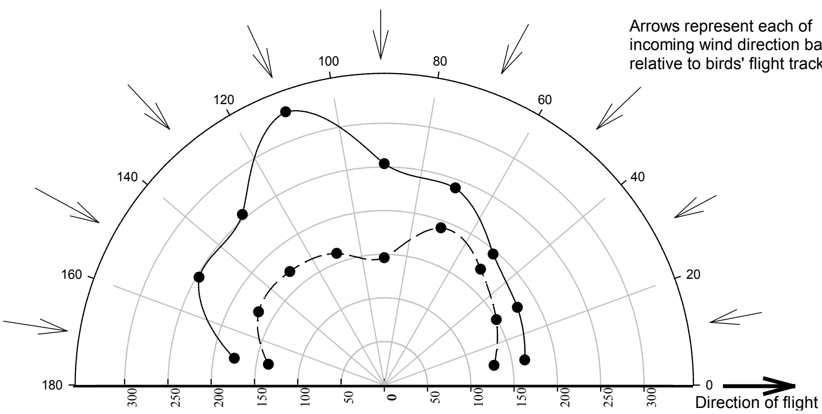


Figure 3. Cumulative distance flown (km, bottom axis) at each wind sector during commute (solid line) and forage (dashed line) phases; means for all 10 birds.

and 160° to 180° - downwind or direct tail wind) caused the southern royal albatross to cover less distance. There was a significant difference between the mean distance covered at more favourable angles (426 km/day) than at less favourable angles (333 km/day) to the wind (t = 3.08; df 7; P = 0.018, Fig. 3). However, mean displacement speed was not found to vary significantly between the wind directions expected to be more favourable (27.6 kph) and those expected to be less favourable (24.9 kph, t = 1.30; df 7; P = 0.235, Figure 4). The difference in mean wind speed at favourable and unfavourable angles (21.63 kph; and 20.07 kph) was not significant (t = 2.01; df 7; P = 0.084).

Discussion

This study suggests that southern royal albatross mainly use a 'commute, forage, commute' strategy during incubation. Southern royal albatross mostly forage at features such as shelf breaks after a period of directed flight. This more closely resembles the incubation foraging behaviour of light-mantled sooty albatross *Phoebetria palpebrata* than the more closely related wandering albatross.

Commute – forage – commute foraging trips are thought to be more energetically costly than the searching looping flights of Crozet Island wandering albatross and Amsterdam albatross, *Diomedea amsterdamensis* (Waugh & Weimerskirch 2003). In long looping flights, the birds achieved a high degree of flight efficiency by optimal use of wind direction (Weimerskirch *et al*. 2000). When flight is targeted on specific foraging destinations, birds may expend more energy by flying at less favourable wind angles and take longer to cover distance. Southern royal albatross were found to spend a greater proportion of their time in flight, and to engage in more flight involving frequent turning (relating to the foraging phase of their trip) than either wandering albatross or amsterdam albatross (Waugh & Weimerskirch 2003). There appears to be a trade-off between these contrasting strategies; flying to sites with relatively predictable prey availability but working harder in flight (southern royal albatross), or flying at minimal cost but taking a chance with sparse and dispersed prey (wandering albatross) increasing their chance of encountering prey items by travelling fast, as more distance is searched per unit of time.

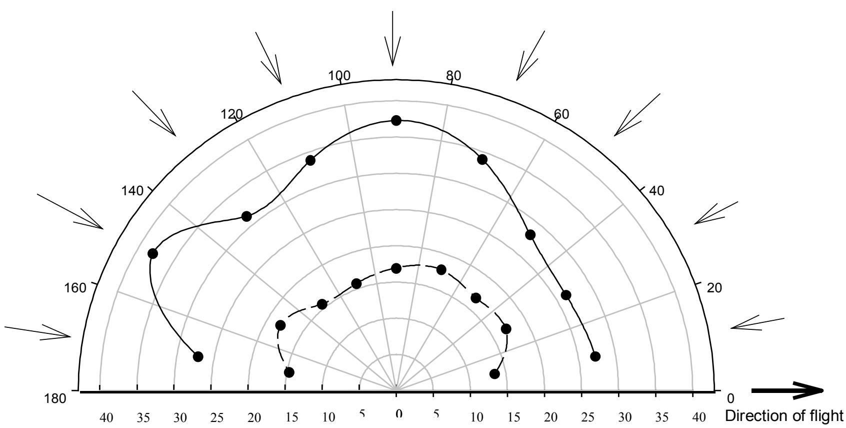


Figure 4. Mean displacement speed (kph, bottom axis) at each wind sector during commute (solid line) and forage (dashed line); means for all 10 birds.

Southern royal albatross may be able to minimise some of the drawbacks of their commute – forage – commute strategy by being selective about when they undertake the commute leg of their trip. The commencements of return trips appear to coincide with an increase in wind speed, and mean wind speed during commuting is significantly higher than during foraging. However, differences in wind speed should be interpreted with some caution. As the wind speed data has a resolution of 12 hours, and wind strength is likely to be stronger in the region of Campbell Island than further north, it is difficult to be certain from these results that change in wind strength is a trigger to departure towards the island, rather than just a feature associated with reaching more southerly latitudes.

Most departures from Campbell Island at the start of foraging trips took place within two to four hours of being relieved at the nest by the returning partner, the longest delay being around six hours. None of the birds in this study encountered low wind speeds during the period following their departure. However, the wind direction at the time of departure appeared to influence the direction taken by the birds, and they made subsequent changes of course as the wind veered. This appears to be different from other seabirds that are unaffected by prevailing winds at colonies (Lawton *et al.* 2008). Wind direction during return trips was favourable (i.e. not head winds) for the course required to fly towards Campbell Island (Figure 2), suggesting the birds may have timed their return accordingly.

Although these findings indicate that southern royal albatross modify their flight plan in accordance with wind direction and speed, they may fly more of a compromise course than wandering albatross so as to reach a site associated with high productivity. Southern royal albatross may fly the best possible course to reach a fixed destination, rather than the most efficient course to no particular destination as do wandering albatrosses (Waugh & Weimerskirch 2003).

Mean displacement speed between successive uplinks was found to be significantly lower during foraging than commuting. During foraging a bird turns more frequently than during commuting but additional turns made between uplinks were not individually recorded. As wind speed was found to be lower during foraging, it is possible that even if flight speed was measured directly it would be slower than during commuting.

Differences in distance covered at different wind angles (Figure 3a) may indicate optimal wind angles for southern royal albatross. During commuting more distance was covered at a wind angle of 100º – 120º than at other angles. Short distances were covered between 0º – 60º (head winds to close reach) and 160º – 180º (direct tail winds). Winds from 100º – 120º may provide maximum energy compared to head winds, while direct tail winds may produce instability. Differences in wind speed did not appear to cause southern royal albatross to adjust their angle of flight relative to wind direction. These results imply that birds in favourable winds did not move more quickly but did less tacking across the wind, i.e. were more able to fly directly to their destination. Nevitt *et al.* (2008) have raised the intriguing possibility that black-browed albatross in foraging portions of their trips may move across the wind in order to maximise their chances of detecting odour plumes from prey. Our results may support this idea in southern royal albatross.

Mean wind speed was found to be similar at any flight angle. This suggests that southern royal albatross do not avoid certain angles in stronger or weaker winds, in contrast to the findings of a study of Gibson's albatross by Reinke *et al*. (1998).

Foraging differences between males and females have been found in other species. Differences in wing loading between heavier males and lighter females can explain sex differences in habitat preference with regards to wind strength. (Shaffer *et al*. 2001) The lightest southern royal albatross in this study, bird C, flew an erratic course taking her further away from the destination of Campbell Island when the wind increased to 30 to 40 kph. She may have been less able to hold a course in strong winds because of a relatively low wing loading. As low mass is an indication of young age, she may also have been inexperienced at navigating the optimal course. In this study, two of the three males (I & J) travelled further south (Figure 2f) than any of the females to the southern edge of the Campbell Plateau, where higher wind speeds are likely. The route taken by these males, however, could have been a function of wind direction at the time of departure from Campbell Island.

This study shows that southern royal albatross have relatively flexible flight behaviour on foraging trips. The birds generally have specific foraging sites that they fly to where they spend much of their foraging phase searching. Given wind direction and strength at the colony at the start of each trip (the timing of which is determined by partner changeover), individuals are able to select appropriate alternative destinations. On the other hand, for the journey back to the colony birds appear to exercise flexibility in timing, waiting for suitable wind direction and strength before initiating their return flight.

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